

FINAL REPORT: "Study of Tropospheric Ozone and UV Reflectivity Using TOMS Data"

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The principal objectives of this investigation were Task I: Study of Tropospheric Ozone using TOMS data, and Task II: Study of UV Reflectivity of the Earth using TOMS data.

We attempted to relate the time history of the changes in tropospheric ozone to their probable causes (*e.g.* biomass burning, industrial activity) using the meteorological data archived by the NCEP/NCAR Reanalysis Project.

In the second task, we inquired into the causes of the interannual variability of TOMS UV reflectivity data, in an independent and rigorous test of the impact of the solar cycle on clouds.

Summary Major Accomplishments

Perhaps the single most important result from the study of Kuang and Yung (1999) is that the interannual variability of the Earth's albedo (especially in Spring) on land is dominated by snow/ice, and not by clouds. This interannual variability could be the major driver of changes in the atmosphere and the biosphere. It is plausible that the interannual variability of snow/ice, through interactions with the atmosphere and biosphere, is responsible for the interannual variability of atmospheric CO₂. By carefully studying the albedo variations off the Peru coast, we found evidence for indirect aerosol effect on clouds. A paper has appeared in *Geophys. Res. Lett.*

Based on a detailed analysis of the cloud data obtained by the International Satellite Cloud Climatology Project (ISCCP) in the years 1983-1991, we show that besides the reported 3% variation in global cloudiness (Svensmark and Friis-Christensen, 1997), the global mean cloud optical thickness (MCOT) also has significant variation which is out of phase with that of the global cloudiness. The combined effect of the two opposing variations may be a null effect on the cloud reflectivity. These results are consistent with the Total Ozone Mapping Spectrometer (TOMS) reflectivity measurements. The MCOT variation is further shown to be correlated with both the solar cycle and the ENSO cycle. Our present analysis cannot distinguish which of the above two provides better correlation, although independent data from the High resolution Infrared Radiation Sounder (HIRS) from 1990 to 1996 favor the solar cycle. Future data are needed to identify the true cause of these changes. A paper has appeared in *Geophys. Res. Lett.*

Using reflectivity measurements from the Total Ozone Mapping Spectrometer (TOMS), we show that over the months when stratocumulus clouds are prominent off the Peru Coast, the ultraviolet (UV) reflectance of two marine sites is consistently higher than that of the surroundings. The regions of reflectivity enhancement coincide with large anthropogenic sulfate aerosol emission sources, and the magnitude of the enhancement has a strong seasonal dependence that is related to the seasonal cloud movement. We propose the indirect aerosol

effect as a plausible explanation for the reflectivity observations. A paper has appeared in *Geophys. Res. Lett.*

We study the impact of the spring snow retreat on albedo from 1979 to 1991 using the ultraviolet (UV) reflectivity measured by the Total Ozone Mapping Spectrometer (TOMS). Over the Northern Hemisphere (NH) snowy land area that was snow covered at least once during this period, we find a 1.5% decrease over the 13 years in the springtime UV reflectivity, related to a $5 \times 10^6 \text{ km}^2$ decrease in the satellite derived spring snow cover. About half of the reflectance decrease occurred over regions where snow cover and reflectance correlate at a 99% significance level. The 1.5% UV reflectivity decrease corresponds to a 1% decrease in the visible albedo over the snowy region, and a similar to 2 Wm^{-2} increase in the shortwave heating when averaged over the entire NH land. Based on observed interannual reflectivity changes over the entire NH snowy land area, our study provides a direct constraint on the shortwave forcing of the spring NH snow retreat. A short paper has appeared in *Geophys. Res. Lett.*

Using the Total Ozone Mapping Spectrometers (TOMS) measurements, we show that ultraviolet (UV) reflectance variations of the polar icy areas are well correlated with the microwave-derived sea ice concentration variations on interannual timescales. We further relate the UV reflectance to the top of the atmosphere (TOA) broadband visible albedo, and show that clouds have reduced the effect of sea ice changes on the TOA visible albedo by more than a factor of 2.

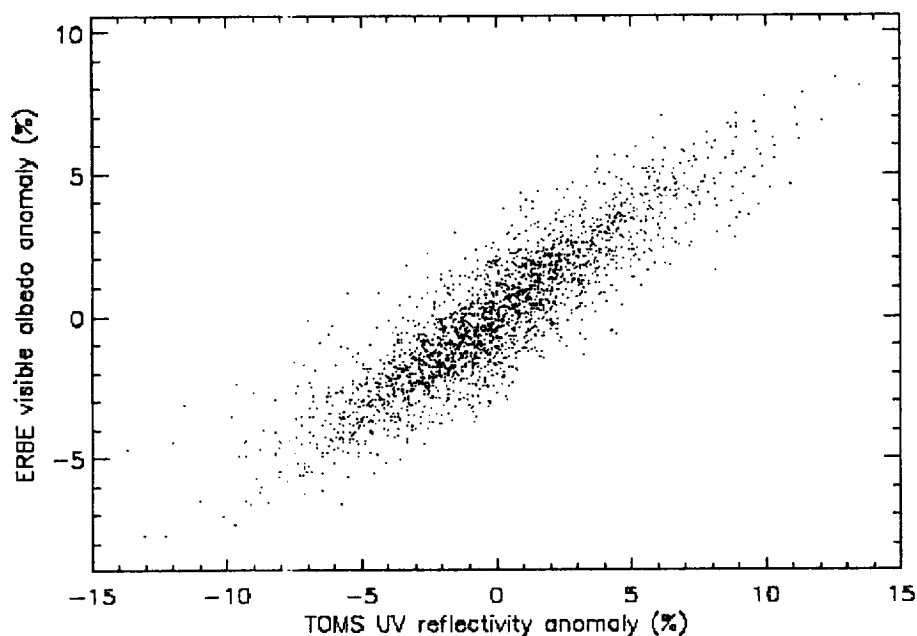


Figure 1. Comparison of ERBE visible broadband albedo variations and the TOMS UV reflectivity variations.

In Figure 1, we relate the TOMS UV reflectance changes to the broadband Earth Radiation Budget Experiment (ERBE) visible ($0.2\text{-}5 \mu\text{m}$) albedo changes over the Arctic icy area, and obtain a linear relation ($r=0.89$) of $0.70 \pm 0.02\%$ visible albedo change per 1% UV reflectance change. From the observed trends and also by linear regression, we estimate a $\sim 0.2\%$ broadband visible albedo decrease per 1% sea ice concentration decrease. This appears to be simply the difference between the TOA albedos of the sea ice covered area and the cloudy area. Note that the value is considerably lower than the albedo difference between ice and water ($\sim 0.5\text{-}0.6$).

This indicates that the TOA albedo effect of the Arctic sea ice changes has been reduced by more than a factor of 2 by clouds.

The recently constructed dataset, combining the monthly mean column abundances collected by the Total Ozone Mapping Spectrometer (TOMS) and the Solar Backscatter Ultraviolet (SBUV and SBUV/2) instruments, provides a nearly continuous record from late 1978 to 2000 on a $5^\circ \times 10^\circ$ latitude-longitude grid. The precision and calibration of these measurements allow very small signals, $\sim 1\%$ of total column ozone, to be clearly seen. Using merged ozone data (MOD), we have carried out an empirical orthogonal function (EOF) study of the temporal and spatial patterns of the interannual variability of total column ozone in the tropics. The first four EOFs of our study capture over 94% of the variance of the deseasonalized data. The leading two EOFs, respectively accounting for 54% and 25% of the variance, display structures attributable to the quasi-biennial oscillation (QBO), with influence from a decadal oscillation (most likely the solar cycle). The third EOF (11% of the variance) represents an interaction between the QBO and an annual cycle. The fourth EOF (4% of the variance) is related to the El Niño-Southern Oscillation. This is the first complete analysis of tropical ozone data using simultaneously the longitudinal, latitudinal and temporal patterns. An important conclusion of this work is that most of the ENSO signal correlates with the 100 hPa geopotential height, thus suggesting a dynamical rather than chemical cause (e.g. biomass burning). A paper based on this work (Camp *et al.* 2002) is in review in *J. Geophys. Research*. The preprint may be viewed in <http://yly-mac.gps.caltech.edu/> under "O₃ Paper".

Publications related to this project

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Conference Presentations

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